LIGHTNING PROTECTION OF QUADRUPLE CIRCUIT 275/132KV TRANSMISSION LINE

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ABSTRACT

This paper presents a comparative lightning performance study conducted on the 275kV and 132 kV transmission line from Kimanis and SPR Power Stations to PMU kolopis and PMU Lok Kawi, Sabah in quadruple circuit shielded transmission line using a software programs, TFlash. The line performance was investigated by using both a single stroke and a statistical performance analysis and considering cases of shielding failure and backflashover. A sensitivity analysis was carried out to determine the relationship between the flashover rate and the parameters influencing it. To improve the lightning performance of the line, transmission line surge arresters were introduced using different phase and line locations. Optimised arrester arrangements are proposed

ABSTRAK

Projek ini membentangkan kajian perbandingan prestasi kilat yang dijalankan ke atas 275kV dan 132 kV talian penghantaran dalam perkongsian menara penghantaran dari Kimanis dan SPR Power Plant ke PMU Kolopis dan PMU Lok Kawi, Sabah dalam empat litar kali ganda untuk melindungi talian penghantaran menggunakan program perisian, TFlash. Prestasi talian telah dianalisis oleh kedua-dua menggunakan kaedah setiap sambaran kilat dengan analisis prestasi statistik dan mempertimbangkan kes-kes daripada kegagalan perlindungan secara langsung dan pancaran kilat kembali ke atas menara penghantaran. Analisis sensitiviti telah dijalankan untuk menentukan hubungan antara kadar kilat dan parameter yang mempengaruhinya. Untuk meningkatkan prestasi kilat talian, penyekat lonjakan talian penghantaran telah digunakan menggunakan fasa pada menara yang terpilih, cadangan pemilihan penyekat lonjakan talian penghantaran di menara dapat dioptimumkan.

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Ω	-	ohms
kA	-	kilo Ampere
kV	-	kilo Volt
m	-	metre
yr	-	year
ACSR	-	All Conductor Steel Reinforced
BS	-	British Standard
CFO	-	Critical Flashover
EPRI	-	Electric Power Research Institute
GFD	-	Ground Flash Density
GIS	-	Geographiral Information System
GUI	-	Graphical User Interface
HV	-	High voltage
JKR	-	Jabatan Kerja Raya
LDC	-	Load Dispatch Centre
LDN	-	Lightning Detection System
LLS	-	Lightning Location System
OHGW	-	Overhead Ground Wirres
PMU	-	Main Substation Intake
SESB	-	Sabah Electricity Sdn. Bhd.
TLSA	-	Transmission Line Surge Arrestor
TNB	-	Tenaga Nasional Berhad

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CHAPTER 1

INTRODUCTION

1.1 Project Background

A fundamental constraint on the reliability of an electrical power transmission system is the effectiveness of its protective system. The role of the protective system is to safeguard system components from the effects of electrical overstress [1]. Therefore, it is necessary to analyse influence of such overvoltages in order to applying the line surge arresters for improving the reliability of designing new transmission line system and for uprating existing lines to higher voltages [2].

Transmission lines are an important part of the electricity supply, and because SESB's transmission network is overhead, the performance of a line against lightning is vital. There are several design options available to improve performance, only some are practical. Where practical [3] the following measures improve lightning performance as in Figure 1.1:

(a) Increase the number of insulators
(b) Add extra earth wires/ shield wires/ improving shielding angles & distance Overhead Ground Wires (OHGW)
(c) Improve footing resistance
(d) Improve coupling between conductors (underbuilt ground wire)
(e) Installation of Line Surge Arrestor/ Transmission Line Surge Arrestor (TLSA)

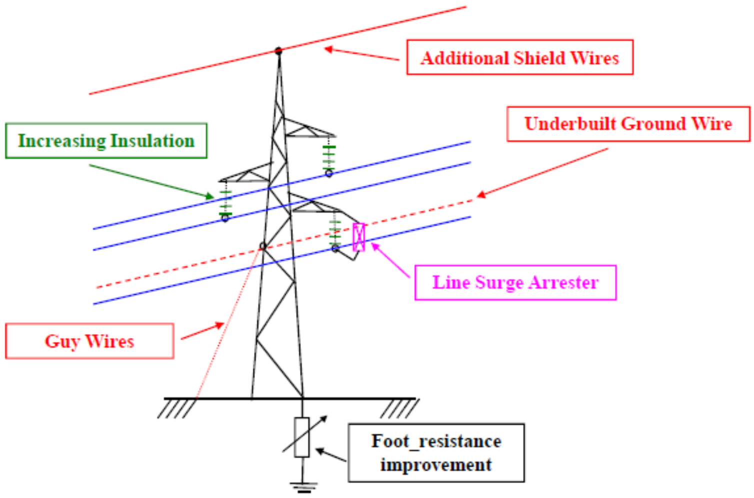

Figure 1.1: How to improve line lighting performance

The total electricity transmission network in SESB is 995 km long as in Figure 1.2. One of the existing longest lines is located in Main Substation Intake (PMU) Kolopis to Main Substation Unit (PMU) Segaliud with 275kV which has a high lightning activity and therefore optimum structure parameters were investigated for reliability.

Figure 1.2: Transmission Sabah Grid
(SESB Transmission Overhead Department, 2013)

Over the last few years, Sabah Electricity Sdn. Bhd. (SESB) have seen a very significant increase in the application of surge arrestors on transmission lines in an effort to reduce lightning initiated flashover, to maintain high power quality and to avoid damages and disturbances especially in areas with high soil resistivity and lightning ground flash density. For economical insulation coordination in transmission and substation equipment, it is necessary to predict accurately the lightning surge overvoltages that occur on a high voltage power system.

Lightning is a natural phenomenon with random behaviour and cannot be prevented. It can only be intercepted or diverted to a path that will, if well designed and constructed, not result in damage and hereafter a complete study of the lightning protection on an overhead line should also include a statistical approach [4]. In this project the establishment of quadruple-circuit 275kV and 132kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah is applied to analysis the lightning protection. Adopting 275kV and 132kV quadruple-circuit transmission lines to transmit power can both economise line corridor and add unit corridor area transmission capacity. Hence line length 2.448km for 275kV and 132kV quadruple-circuit is implemented in this project.

The method used to analyse the increase in voltage due to lightning was done by using the lightning detection method and flash data source. Detailed sensitivity analysis studies were carried out to determine the relationship between the flashover rate and the parameter influencing it, such as tower footing resistance, ground flash density and front time of the lightning impulse. Lightning faults are of four types as Figure 1.3:

(a) the flashover of shielding failure, mainly single-phase, following a screen failure and caused by direct hitting to the phase conductors;

(b) the backflashovers, which can occur when the lightning strike hits a tower or the earth wire;

(c) the induced flashover, which stroke to another object or ground;

(d) the midspan of flashover, which stroke the shield wire to phase or vice versa

In this case, the potential at the top of the tower rises in an important way and can exceed the dielectric strength of the insulators string [5].

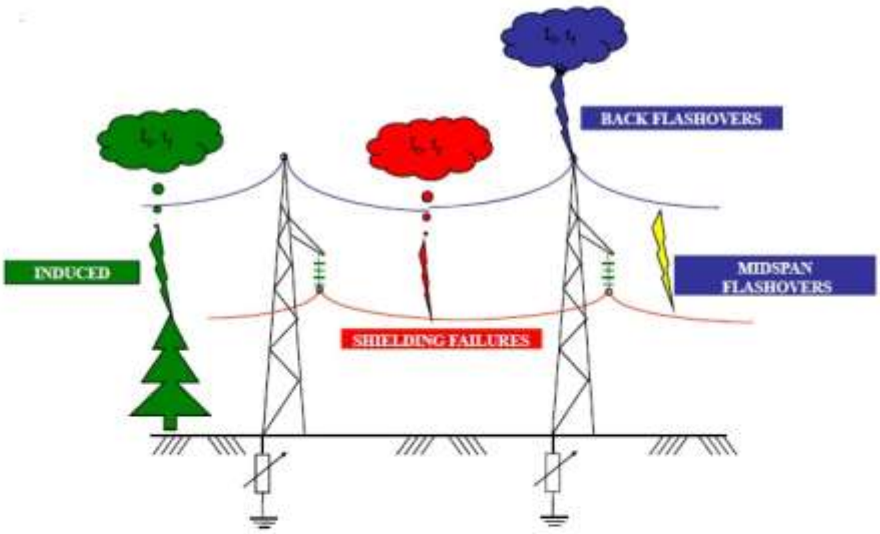

Figure 1.3: Line lightning performance

1.2 Problem Statement

Lightning is one of the most significant sources of overvoltages or line faults in overhead transmission lines. Lightning strokes to overhead transmission lines are a usual reason for unscheduled supply interruptions in the modern power systems. Field study indicates that more than 90% lightning stroke outage accidents for high voltage (HV) transmission lines are caused by shielding failure flashover [6]. The lightning overvoltages could lead to failure of the devices connected to the transmission line. Between 5% to 10% of the lightning caused faults are thought to result in permanent damage to power system equipment [2].

Lightning cannot be prevented but it can be intercepted with some success, and its current can be conducted to a grounding system without side flashes where it is harmlessly dissipated. In case of the lightning strokes landing on a conductor, tremendous amount of over voltages waves will travel on the lines from striking point [7]. Lightning arresters are used in this protection but lightning arresters need every phase in each tower, so this way is very expensive. It is investigated studied the severity and frequency of thunderstorms in the local area for sample and study the worse lightning performance tower of the protection of lightning strokes for transmission lines to install them.

The reasons for the worse grade of lightning flashover performance of towers are obtained simultaneously through the method, which would increase the technology-economy rate for the improvement of lightning performance of transmission lines. Evaluation of lightning flashover risk provides a good strategy for power supply companies to master and improve the lightning performance of HV overhead transmission lines [8].

As lightning is a second major source of faults on overhead lines and damages to or malfunction of sensitive electronic equipment in Figure 1.4 thus, consequently resulting in economic losses. SESB is essential to evaluate the lightning environment in order to mitigate its effects and improve the reliability of power system quality. More recently, many studied have been carried out, especially on high voltage lines aiming at obtaining a better understanding of the characteristics of the lightning overvoltages.

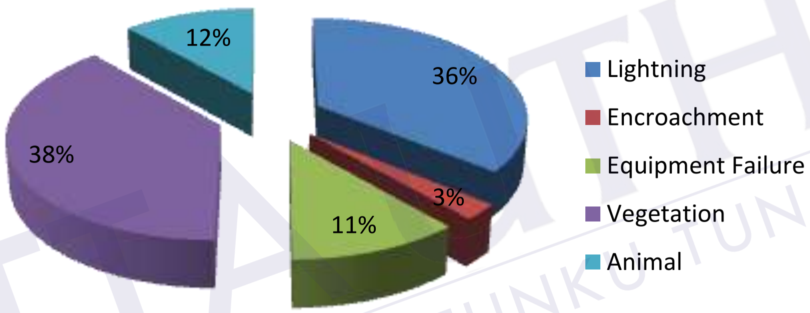

Figure 1.4: SESB transmission line tripping records for FY2012/ 2013 (http://ppb.sesb.com.my/sislgb, 2013)

The economical criterion is accounted as the objective function to develop a computer program for designing lightning protection systems for transmission lines by using T-Flash in this work. For the purpose of improving the stability and robustness of transmission network in SESB, a dynamic lightning location system in Figure 1.5 which based on real time lightning detection was developed to minimize the harmful effects of lightning by providing early warning of such lightning hazards.

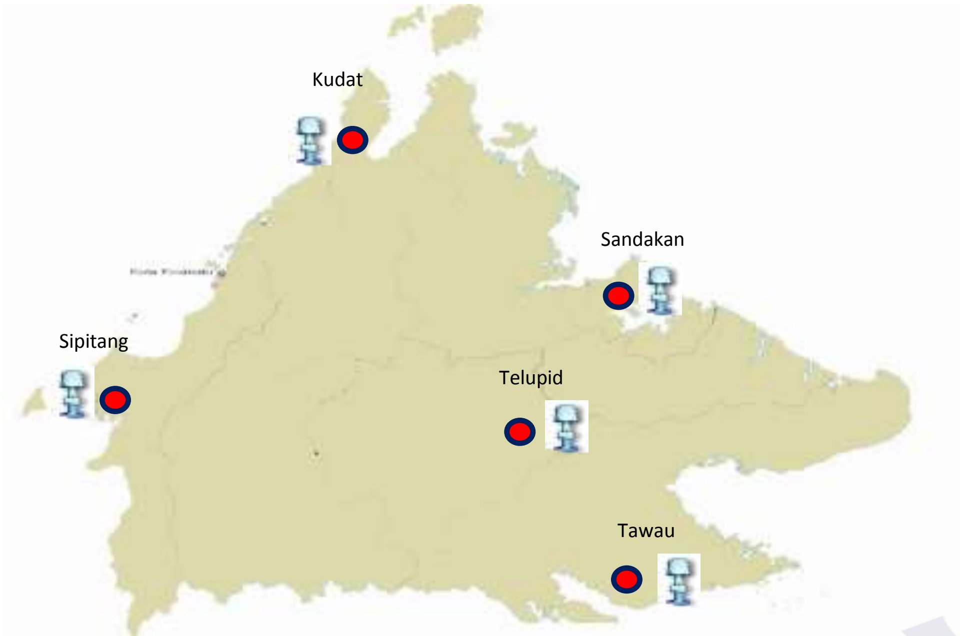

Figure 1.5: Sensors lightning detection in Sabah
(SESB Transmission Protection Department, 2013)

1.3 Project Objectives

The transmission line performance was investigated by using a single stroke and statistical performance analysis and considering cases of shielding failure and back flashover. A lightning arrester with a series gap for transmission lines has been developed to prevent faults due to lightning, which has shown excellent performance services lines in heavy lightning region [9]. Its measurable objectives are as follows to improve the lightning performance of the line:

(a) To determine the relationship between the flashover rate and the parameters influencing it in order to install the Transmission Line Surge Arrestor (TLSA).

(b) To optimise the arrester arrangements for practical applications in term of cost and efficiency.

1.4 Project Scopes

Transmission systems are required to provide high levels of reliability to maintain and to increase the marginal return on the electric service provided [10]. The costs and benefits to the customer of improving lightning performance have been applied.

There are several means of improving the lightning performance of transmission lines. Improvement costs range from extraordinary expensive to very moderate.

This project develops the preceding work in three different stages. At the first, considers the ground flash density (number of flashes per squares kilometre). Secondly, transmission line arrestors are installed on selected tower after performing the foregoing investigations when no line surge arrestors were installed on the towers. This allows the possibility of determining appropriate arrestor configurations for reduction of line outages. Transmission line arrestors are shown to be an important consideration in determining the lightning performance of the line in preventing line failures [11].

The parameters that affect transmission line lightning performance fall into two broad categories:

(a) Those that affect lightning incidence to a line.

(b) Those that affect the development of insulator and air gap voltages when lightning hits a line or hits the earth near a line.

Lightning performance calculations are useful for the comparison of line designs in the same meteorological environment. Such analyses allow the designer to select one design from many with the understanding that while the absolute performance of the line may be uncertain. The design is the best option evaluated based on performance requirements. These include, tower footing resistance, soil conditions and terrain (resistivity), tower dimensions, span length and the estimated average ground flash density (GFD) where the line is to be located.

It is possible to perform some limited lightning performance calculations manually, but the evaluation of multiple design options generally requires the use of a high-speed computer. Transmission line lightning computer programs forecast an average expected flashover rate by first assuming a prescribed average lightning incidence to a line that is based on average or median thunderstorm weather records.

To improve the lightning performance of the line, the application of TLSA was studied using different arrester configurations and locations. The computed results indicate that arresters installed on the top phase of each circuit give the most significant improvement in lightning performance when combined with low tower footing resistance. Optimised locations of surge arresters were then derived for practical applications.

Economically arresters should not be installed at all phases for better line performance [11]. It is imperative to conduct a thorough study to identify the best possible arrangements to install the arresters parallel with the phase insulators. Arresters installed at proper locations enhance the decrease of line outages relating to backflashovers and shielding failures.

1.4.1 Earthing Measurements

The earthing system at transmission level comprises two main components which are the earth grid and an extension of the earth electrode system which is determined by the transmission tower lines [12]. Based on this project, the protection of transmission towers against lightning recommends that the designing of earthing system intended to protect against lightning strikes should have an earthing resistance fixed on 10Ω due to British Standard (BS), Code of Practice for Protection of Structures [13]. This seems to be the only transient earthing system design limit specified and has been adopted by national power utilities provider such as Tenaga Nasional Berhad (TNB) and Sabah Electricity Sdn. Bhd. (SESB). Although the standard recognises the importance of the inductive effects, the design limit appears to be based on resistance. The standard also recommends that the down conductor should be directly routed to the earth electrode.

1.4.2 Designing Earthing System

Earthing or grounding is the art of making an electrical connection to the earth. The process is a combination of science and art as opposed to pure science, because it is necessary to test the options, as opposed to using predetermined methods and calculations. The options for each site must be determined through visualization and evaluation, individually, using a related analytical process [14].

The earth must be treated as a semiconductor, while the grounding electrode itself is a pure conductor. These factors make the design of an earthing system complex, not derived from a simple calculation or the random driving of a few rods into the soil. Knowledge of the local soil conditions is mandatory and is the first step in the design process. This includes its moisture content, temperature, and resistivity under a given set of conditions.

In this project, the earthing conductor shall be laid vertically and radially from the object to be earthed and the number of advanced radial earth conductors limited to 6 lengths for each tower. The length of each radial conductor is to be adjusted depending on the conductivity of the soil.

1.4.3 Variability of Soils Resistivity

The accurate measurement of soil resistivity and earthing system resistance is fundamental to electrical safety. However, geological and meteorological factors can have a considerable effect on the accuracy of conventional measurements and the validity of the measurement methods. This project based on the impact of soil resistivity on earth electrode grounding by carrying out extensive measurement of tower footing earth electrode resistance and soil resistivity along the 275kV and 132kV transmission line from Kimanis and SPR Power Stations to PMU Kolopis and PMU Lok Kawi, Sabah using the seismic survey and JKR Probe study method. The project examines some aspects of earthing measurements and earthing system performance in the context of both geological and meteorological effects.

1.4.4 Ground Flash Density

Sabah has unequal lightning ground flash density all over the country, so consideration of lightning effect on the line is considered. Power outages reports Figure 1.4 from SESB transmission line tripping records which was analysed and the results indicated that most power outages were due to lightning. The high number of power outages that are attributed to lightning does not only affect Sabah but also other countries all over the world.

The annual number of lightning flashes influencing a transmission tower to be protected depends on the thunderstorm activity of the Sabah region where the 5 lightning detection are located and on its physical characteristics. It is generally accepted that this number can be evaluated multiplying the lightning ground flash density, that is, the number of flashes per square kilometre and per year, by an equivalent area of the object. In the past, due to the lack of direct lightning measurements, the ground flash density was generally inferred from the thunderstorm days per year, or the keraunic index, through an equation containing empirically derived constants. This index is available with very low resolution in almost all countries around the world. This practice is still adopted in many lightning protection standards, including the Sabah Electricty Sdn. Bhd. lightning protection standards.

In this paper, lightning data in the Sabah region for a period of three years, from 2011 to 2013, obtained by the Vaisala Lightning Detection System is used to discuss how the ground flash density should be considered in terms of spatial resolution and minimum time interval of observations. In order that, 65 ground flash density was chosen for this project.

1.4.5 Tower Geometry

Tower height is an important parameter in the insulator voltage development process. A typical transmission tower might have an equivalent inductance on the order of 20 mH, and a lightning surge current flowing down the tower, changing at a rate of 75 kA/ms, would create a tower-top voltage of 1500 kV with respect to ground. A substantial part of this voltage appears at the tower crossarms, and consequently, across the line insulators connected to the crossarm [15].

Tower shapes and heights vary widely with a ground wire to tall transmission structures. Some towers have shield wires stretching out to earth anchors that further complicate the analysis of their electromagnetic contributions to insulator voltage. Whatever the tower geometry, the following two fundamental parameters are needed for analysis:

(a) Tower height - The tower height determines the travel time of lightning transients from top to bottom. All other variables being equal, if the tower height is doubled, the inductive component of voltage across each insulator will approximately double.

(b) Tower surge impedance - A transmission tower can be regarded as a network of metallic elements, each with a finite travel time for any transient current moving along it. In effect, the tower becomes a network of short transmission lines carrying current from the tower top shield wires to the earth below, where some of the current enters the earth resistance and some reflects back up the tower toward the top. As such, the tower can be considered a short vertical transmission line, and like any transmission line it has "surge impedance" describing the voltage produced on the tower per unit of current flowing through it. This surge impedance is different for different tower geometries. A rough value for a conventional lattice tower might be 150 ohms, but this can vary substantially. The contributions of tower surge impedance to lightning voltages across insulators are discussed in more detail in [15].

1.5 Thesis Structure

Chapter one: The introduction chapter set the scene and introduces the thesis.

Chapter two: A description of the theory of lightning. This chapter includes things to evaluate lightning activity by using spatial clustering and the theory behind lightning surge impedance computation. Besides that, analytical method, Flux3D software and lightning detection network have been clarified in this section.

Chapter three: A description of project method by calculation and simulation for 275kV and 132kV quadruple-circuit.

Chapter four: Data analysis of the project includes the site study and the calculations done. The discussion is evaluated in this chapter.

Chapter five: Gives the overall including suggestions for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Transient outages are a primary concern for SESB trying to improve their power quality. Improving protection of overhead transmission lines from lightning is one way in which SESB can significantly reduce the number of momentary outages. A computer program can help analyse various methods of improving the protection of transmission networks without field tests [16]. Many variables can be adjusted to measure their impact on the design.

Lightning warning is an essential means and a key technology for lightning disaster reduction. Passivity is the main drawback of existing lightning warning methods. A lightning prediction technology based on spatial clustering method to predict lightning motion by utilizing real-time and historical lightning monitoring data of lightning location system was studied. On the contrary to the existing passive lightning prediction and warning methods, this technology initiatively predicts the prospective lighting area. The independent, discrete, random-happen flashes are aggregated to different thunderstorm groups similar to thunderclouds by the spatial clustering method. The position prediction of lightning can be achieved by tracking these thunderstorm groups and calculating the movement direction and speed of them [17].

Traditional analytical method using simplified equations and the finite element method for the mapping of electromagnetic field surrounding the tower to compute of transmission line tower surge impedance. In the latter were used a software, the commercial software FLUX3D. It is able to perform calculations based in a 3D representation of the problem to perform computations. It is also verified the impedance variation along the tower height, phenomenon that most of the time is not considered, and that can provide a direct impact in the performance of transmission lines facing the atmospheric discharges [18].

The cause of lightning accident of transmission line is due to characteristics of lightning data, so it is very important to count and study the characteristics of lightning parameters. The monitoring method of lightning location system has substituted for the traditional method of collecting lightning data. With the new method, more lightning parameters can be detected, such as the lightning striking location, intensity, strike back times and intensity effectively. The result of analysis can provide basic data for the lightning proof of HV transmission line, and valuable references to improve the lightning-shielding level of a transmission line and decrease the impact of lightning on the safe operation of power systems.

In order to verify the feasibility of the model, we had contrasted the lightning density with different topography of a HV transmission line. Besides that, the structure of line and the design of insulation had considered, and to compare multi-segment lines with the same landscape through data analysis to find out which is the main factor causing the different lightning density. According to these differences to draft corresponding solutions and improve the lightning proof of transmission line. It is noted that the lightning protection level of transmission line is not only correlated with the design of lightning-proof, but also with lightning activity data based on lightning location system (LLS). It is needed to pay attention to lightning activity data analysis, design of lightning-proof, structure of transmission tower, and insulation co-ordination. Finally, make a reasonable decision for lightning proof [19].

2.2 Theories

Lightning has several impacts on the environment. One of them is causing trips of transmission lines. Although there are many publications about lightning, there is still more to learn. In SESB, the majority of transmission lines are overhead and so are exposed to the lightning that occurs in a sub-tropical climate. Therefore the study of effects of lightning on transmission lines is important.

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